FLOOD PLAIN INFORMATION

YELLOWSTONE RIVER

LIVINGSTON MONTANA

PREPARED FOR
PARK CCUNTY
AND
MONTANA DEPARTMENT OF NATURAL RESOURCES
BY
DEPARTMENT OF THE ARMY — OMAHA DISTRICT — CORPS OF ENGINEERS 68102
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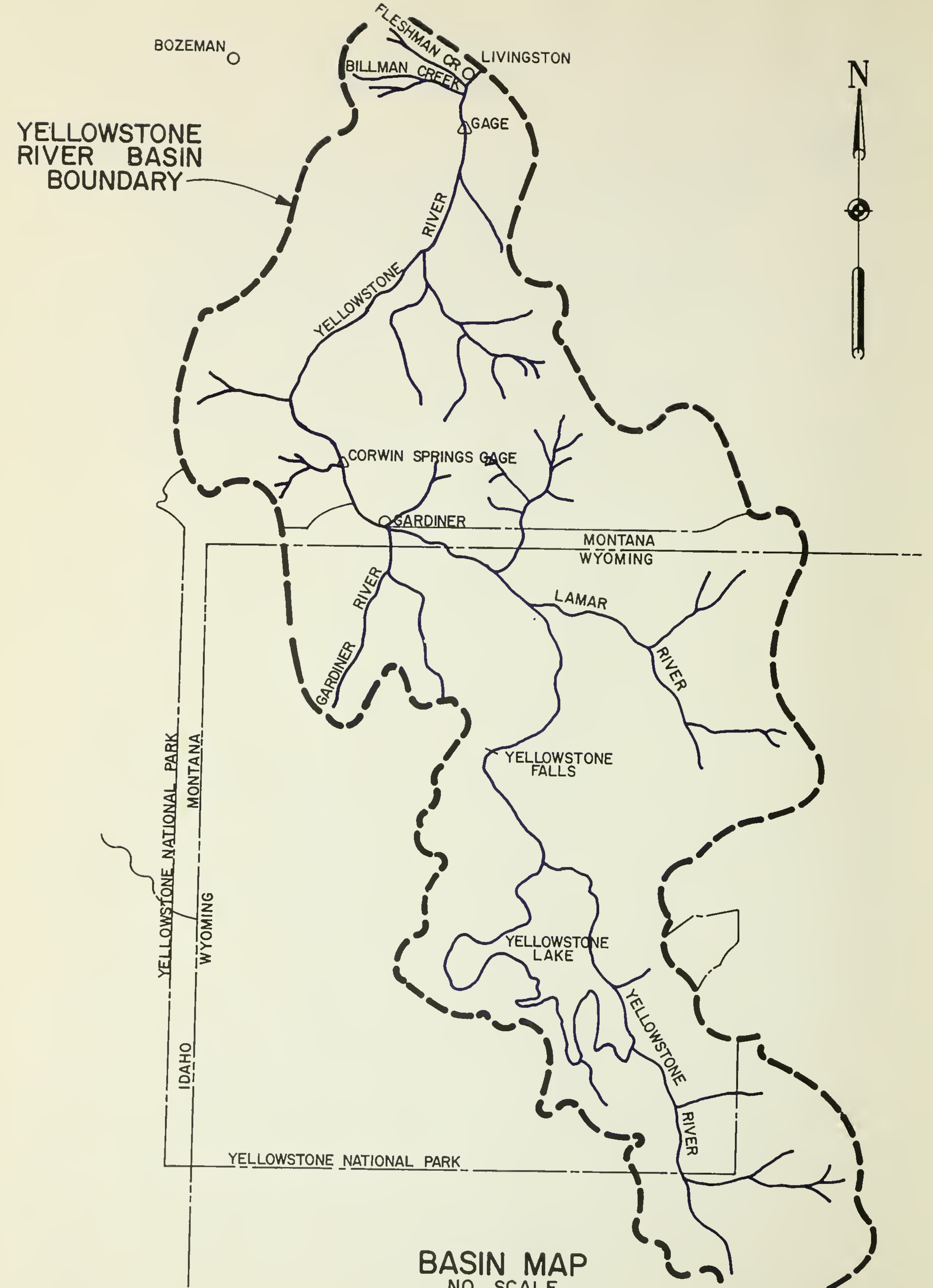


BASIN MAP
NO SCALE

PLATE I

PREFACE

This report describes the flood characteristics of the Yellowstone River from about six miles upstream to about six miles downstream from the city of Livingston, Montana. The areas subject to flooding from the Yellowstone River within this study reach are primarily agricultural, recreational, residential, and commercial lands.

This report was prepared for the guidance of local officials in planning the use and regulation of the flood plain. Two potential floods are used to represent degrees of major flooding that may occur in the future. These two floods, Intermediate Regional and Standard Project Floods, are defined in the glossary and should be given appropriate consideration in planning for safety of development in the flood plain. The two potential floods are further defined by flooded area maps that show the approximate areas that would be inundated. Flood profiles show the water depths relative to the streambed and flood elevations across the width of the valley. Cross sections are presented to indicate ground level across the valley and the overlying flood depths. The flood profiles and flooded area data presented are based on existing conditions of the basin, stream and valley when the report was prepared. Further urbanization of the drainage basin may increase runoff and flooding. Possible future improvements to control floods are not a consideration of this report. The information in this report does not imply Federal interest or authority to zone or regulate use of the flood plains; this is a local responsibility. The report provides a suitable basis for the adoption of land use controls to guide flood plain development, with consideration for environmental attributes, and thereby prevent intensification of loss problems. Since it identifies flood problems, the report will stimulate the development of other flood damage reduction techniques such as flood control, removal of obstructions and flood proofing, which might be used in an overall Flood Plain Management (FPM) program.

This report was prepared by the Omaha District, Corps of Engineers, in accordance with the authority granted by Section 206 of the Flood Control Act of 1960 (Public Law 86-645) as amended. The study was requested by Park County, Montana through the Montana Department of Natural Resources.

The assistance and cooperation of County and City officials, as well as private organizations and individuals in providing information and other data was most helpful.

Distribution of the report to officials, agencies and individuals concerned with planning in the area covered is made by Park County. The Corps of Engineers will provide interpretation and technical assistance, if requested, in application of the report data. Other guidelines available from the Corps of Engineers are a pamphlet, "Guidelines for Reducing Flood Damages" and a booklet, "Introduction to Flood Proofing".

BACKGROUND INFORMATION

SETTLEMENT

The first white people entered the Livingston vicinity on 15 July 1806. They were members of the Lewis and Clark expedition enroute to St. Louis, Missouri. Historical documents indicate that the party spent three hours at the present site of Livingston resting and grazing their horses before continuing down the Yellowstone Valley. During the next three decades following the Lewis and Clark expedition, the area was intermittently frequented by hundreds of men engaged in trapping fur-bearing animals, especially beaver. The area remained relatively quiet until 1862 when gold was discovered at Bannack, Montana. This discovery and those in the area that followed brought thousands of people through the Livingston area in the 1860's and 70's. The area during the early part of this period served as the point where travelers left the Yellowstone River and travelled overland across the mountains to the West. Later, people such as ranchers and businessmen came to the Livingston vicinity interested in establishing a permanent settlement. In 1868 a small settlement known as Benson's Landing was established along the Yellowstone River four miles east of the present site of Livingston. It remained a focal point in the area for many years. Then in 1879 the town of Clark City was founded at the present site of Livingston. However, unknown to the citizens of Clark City, the Northern Pacific Railroad established on their maps the name of this town as Livingston in honor of Crawford Livingston, a Northern Pacific director. The new town continued to grow in anticipation of the coming of the Northern Pacific Railroad which reached Livingston on 22 November 1882. Later, in 1888, Livingston became incorporated.

Livingston today is a modern progressive community boasting churches, a hospital, newspapers, a radio station, and industrial and commercial interests. It is the county seat of Park County - a county comprised of areas devoted to such enterprises as farming, ranching, lumber production, and recreation.

THE STREAM AND ITS VALLEY

The Yellowstone River is located in the upstream reaches of the Missouri River Basin. It originates near the southeast corner of Yellowstone National Park near the Continental Divide in southwestern Park County, Wyoming. From its source near elevation 12,000 feet mean sea level (m.s.l.), it flows northerly to Livingston, Montana via Yellowstone National Park and Yellowstone Lake. Its valley through this reach varies from steep, winding, mountain canyons to wide, open valleys bordered by high mountains. Downstream from Livingston the river flows in a general northeasterly direction across southeastern Montana to its confluence with the Missouri River in West Central North Dakota near Buford, at elevation 1860 feet m.s.l. This portion of the river valley is essentially open and wide and is used primarily for agricultural purposes.

The Yellowstone River Basin comprises an area of 70,000 square miles of which 3600 square miles are located above Livingston. The following table gives climatological data for the Yellowstone River Valley.

Table I

Yellowstone River Valléy Climatological Data

Location	Mean Annual Precipitation (inches)	July Mean Temperature (° F)	January Mean Temperature (° F)
Upstream Reach (Yellowstone Lake, WYO)	20.7	55.4	10.6
Livingston, MT	14.7	67.7	25.7
Downstream Reach (Savage, MT)	14.1	70.8	12.1

At Livingston, Montana, the highest and lowest temperatures ever recorded were 106°F and -45°F respectively.

The reach of the Yellowstone River studied in this report is approximately 14.9 miles long measured along the main channel centerline. It begins about 1/2 mile upstream from the confluence of the Yellowstone River and Suce Creek and ends approximately 1/8 mile downstream from the mouth of the Shields River. This reach of the river has, at various points, more than one channel thus forming intermittent islands. The Yellowstone River falls an average of 13.5 feet per mile within the confines of the study reach. The river depth below bankful ranges from approximately 8 to 20 feet with the average depth being around 15 feet. The flood plain widths as defined by this study vary considerably as one progresses down the river. Above reference point 4 the flood plain width averages approximately 1800 feet. Farther downstream in the canyon area below the Carter Bridge (reference point 5) the flood plain narrows to a minimum width of 1100 feet. From this region downstream to Interstate 90 at reference point 13 the flood plain averages 2200 feet in width. Between Interstate 90 and U.S. Highway 10 at reference point 22 the average width is 2700 feet. From U.S. Highway 10 to the downstream limit of the study reach the flood plain averages 4,000 feet wide but ranges to as much as 6,000 feet. The photographs on pages 4 through 8 show existing conditions along the study reach.

Figure 1. Looking upstream from 500 feet downstream of reference point 3. September 1974.

Figure 2. Looking downstream from 500 feet downstream of reference point 3. September 1974.

Figure 3. Looking upstream at the Carter Bridge (reference point 5) from the right bank. February 1974.

Figure 4. Looking upstream from the Interstate 90 bridge (reference point 13) at Siebeck Island. September 1974.

Figure 5. Looking downstream from the Interstate 90 Bridge (reference point 13) at Ninth Street Island. September 1974. Note what appears to be sandbags adjacent to the white building evidently remaining from the flood of June 1974. Note also that the right edge of Figure 5 blends with the left edge of Figure 6 making one continuous photograph.

Figure 6. Looking downstream from the Interstate 90 Bridge (reference point 13) at Ninth Street Island at the left and in the far background.

Figure 7. Looking upstream from the U.S. Highway 10 bridge (reference point 22). September 1974.

Figure 8. Looking downstream from the Burlington Northern Railroad bridge (reference point 23). September 1974.

Figure 9. Looking upstream at the U.S. Highway 89 bridge and the Burlington Northern Railroad bridge (reference points 30 and 29 respectively). February 1974.

Figure 10. Looking downstream from the U.S. Highway 89 bridge (reference point 30). September 1974.

DEVELOPMENT ON THE FLOOD PLAIN

Development on the flood plain as defined in this report is primarily associated with Livingston, a city having a 1970 population of 6,883. Flood plain development has not only occurred within the confines of the Livingston city limits, but also in flood plain areas adjacent to Livingston, especially between Livingston and the Yellowstone River canyon area located to the south in the vicinity of the Carter Bridge (reference point 5). South of the Carter Bridge the flood plain is used primarily for agricultural purposes. Downstream from the Carter Bridge more development, especially residential, is present. This development, due to accessibility, is confined mainly to the left bank of the Yellowstone River and to islands. Siebeck Island remains relatively undeveloped. It does, however, contain a gravel mining operation and limited residential development. Just downstream lies Ninth Street Island. This island contains a rather substantial amount of residential area and recent construction is evident. Both of these areas are located between active river channels. Livingston Island, located just downstream from Ninth Street Island, lies between the Yellowstone River and an old river channel. This channel, which was sealed off by the city in 1921 and 1923, is now called Sacajawea Lagoon and is part of the city park development. The island contains some development ranging from residential to commercial to public facilities. Farther downstream is Riverside Addition located between the Burlington Northern Railroad and Sacajawea Lagoon. This area contains considerable residential development. Downstream from the Burlington Northern Railroad (reference point 23) land use is essentially agricultural. Throughout this study reach, the flood plain contains numerous streets and roads as well as U.S. Highways 10 and 89 and Interstate 90 and railroad service provided by Burlington Northern.

FLOOD SITUATION

SOURCES OF DATA AND RECORDS

Flow records for the study reach of the Yellowstone River are available from a United States Geological Survey water stage recorder gage located four miles south of Livingston. The drainage area at the gage is 3,551 square miles. Records at this gaging site date back as far as 1897.

Information on past floods was obtained from Corps of Engineers flood records and from past issues of the Livingston Enterprise. Photographs used in the report are by the Corps of Engineers. Cross sectional survey data obtained specifically for this report in the summer of 1973 was obtained by the Corps of Engineers using services of the U.S. Geological Survey. The U.S. Geological Survey provided high water mark data corresponding to various flood events. Twenty-foot contour interval U.S.G.S. quadrangle maps were also used in the study. Aerial photographs used for the flooded area mosaic in the report were obtained by the Corps of Engineers in October of 1973 using the services of the Montana Department of Highways. The aerial photographs of Figures 11 through 14 were also obtained by the Corps of Engineers.

FLOOD SEASON AND FLOOD CHARACTERISTICS

The gaging records show that the peak annual floods on the Yellowstone River have occurred during May and June. These floods have historically been due to mountain snowmelt supplemented in part by rainfall.

FACTORS AFFECTING FLOODING AND ITS IMPACT

<u>Obstructions to floodflows</u> - Seven roadways, both highway and railroad, cross the entire Yellowstone River flood plain within the confines of the study reach. Roadways which are elevated above the flood plain can obstruct flows and create greater upstream flood depths. If they cross the flood plain at an angle they can divert water, increasing the flooded area. The severity of these obstructions and diversions and the ensuing damage depends upon the magnitude of the particular flood event. During

the flood of June 1974, the Burlington Northern Railroad bridge (Reference point 23) sustained damage when the large floodflow passing through the bridge caused the south portion of the middle bridge pier to crack and settle.

Trees, brush, and other forms of vegetation, manmade objects such as buildings and cars, and miscellaneous debris located on the flood plain can cause flow obstructions. These items, while remaining in place, not only tend to create higher stages on the flood plain due to reduce flow area and flow blockage, but may also create higher localized velocities as the floodwaters flow around specific items. If the floodflows are of such a magnitude so as to dislodge the debris, flood stages may lower in that localized area, but the debris can become lodged farther downstream against other flood plain obstructions thus compounding problems. This floating debris commonly lodges against bridge piers or bridge decks reducing flow area, or if severe enough, causing complete channel blockage. These situations can cause severe stage and velocity increases accompanied by bridge damage or complete failure.

Ice can also cause a flow obstruction problem similar to that described above for debris. However, this does not appear to be a frequent threat in the study reach since records indicate that only two flood events were ice affected during the 50 years of gaging records.

Flood damage reduction measures - There are no large flood control structures on the Yellowstone River within the study reach. In June 1955, the Corps of Engineers completed an emergency bank protection project on the left bank of the Yellowstone River at Livingston between 11th and 12th Streets. Local interests have conducted bank protection projects at various locations throughout the study reach, especially in the Livingston vicinity. They also have constructed low levees along a portion of Livingston Island and at other locations. Some of these were constructed in anticipation of the June 1974 flood. Levees constructed by local interests along the left bank of the Yellowstone River from reference point 15 to reference point 17 are such that a successful flood fight can

possibly be waged along this reach in the event of an Intermediate Regional Flood. However, due to the irregularity of this levee top, for the purposes of this report, this levee was considered unable to protect against the Intermediate Regional Flood. As mentioned earlier in the report, the city of Livingston, in 1921 and 1923, constructed channel blocks to eliminate the Yellowstone River flow from what is now called Sacajawea Lagoon. The city of Livingston has enacted specific regulations or ordinances governing construction in that portion of the flood plain located within the Livingston city limits known as St. Mary's Addition. This area is roughly bounded by Sacajawea Lagoon on the north, H Street on the east, the Livingston city limits on the south, and the west boundary of Section 18, T2S, R10E on the west. No evidence of flood proofing of structures in the flood plain is apparent other than that provided by emergency measures such as sandbags.

Other factors and their impacts - Several smaller streams join the Yellowstone River within the study reach of this report. They are Billman Creek, Fleshman Creek, Slaughterhouse Creek, and the Shields River, which are left bank tributaries of the Yellowstone River and Suce Creek, Dry Creek, Chicken Creek, and Poison Spider Creek, which are right bank tributaries. None of these streams were studied in this report. Fleshman and Billman Creeks especially, pose flood hazards to existing development associated with the city of Livingston. High water flows from Fleshman Creek can enter the Livingston business district. Likewise, Billman Creek can inundate primarily residential area west of Siebeck Island. The flood hazard presented by all of these streams can be reduced by implementing flood warning systems, flood emergency plans, and sound flood plain management concepts.

Flood warning and forecasting - The National Oceanic and Atmospheric Administration National Weather Service provides flash flood warnings for the Livingston area through their Billings, Montana office. Livingston is located within the effective weather service radar network

which has the capability of detecting areas of intense precipitation. River stage forecasts are issued for the Yellowstone River at Livingston when conditions require. The river district office at Billings is responsible for the distribution and interpretation of flood forecasts.

Flood fighting and emergency evacuation plans - Provisions for alerting area residents through local communications media and coordinating operations for flood fighting are available by the Park County Civil Defense Office. This office is also coordinating activities to formulate a flood disaster plan for the Livingston vicinity.

Material storage on the flood plain - Often floatable material stored on the flood plain is washed away during floods to collect at points downstream. The flood plain in the study reach is relatively clear of such materials. Where stored, floatable material is present on the flood plain, securing the material in some fashion will insure against its creating an additional flood hazard. Other floatable material such as loose trees, branches, and logs is clearly evident along sandbars and flood plains adjacent to the river. This type of material is located all up and down the Yellowstone River and its tributaries and can pose serious debris problems during a flood event.

PAST FLOODS

SUMMARY OF HISTORICAL FLOODS

Nine major floods have occurred on the Yellowstone River in the Livingston area since 1894. These floods occurred in June 1894, June 1918, June 1921, May 1928, June 1943, June 1948, June 1971, June 1972, and June 1974. The floods have been caused by the rapid melting of snow in the upstream areas. The highest discharge at Livingston on the Yellowstone has been 35,300 c.f.s. which occurred in 1974. Prior to the construction of levees by the city, portions of Livingston Island and Riverside Addition were flooded almost annually, but subsequent flood damages have been relatively low. However, the levees only provide minimal protection against large floods.

Flooding is also caused by Billman and Fleshman Creeks from the west portion of the city. These tributaries to the Yellowstone River flood primarily from intense rainfall in the hills south and west of Livingston. Some of the heaviest damage to Livingston has been due to the floods from Fleshman and Billman Creeks.

FLOOD RECORDS

Flows of the Yellowstone River at Livingston are recorded by a U.S.G.S. water-stage recorder located about 4 miles south of Livingston. The drainage area at the recording station is 3,551 square miles. The datum of the gage is 4,542.49 feet above m.s.l., datum of 1929. Natural regulation of the river flows is provided in part by Yellowstone Lake upstream from the gage. Diversions for irrigation do not materially affect peak flows.

Table 2 shows the dates, peak discharges, and gage height for some of the larger discharges occurring on the Yellowstone River at the Livingston gage since 1897.

TABLE 2

PEAK STAGES AND DISCHARGES FOR THE
YELLOWSTONE RIVER NEAR LIVINGSTON[1/], [2/]

Date	Gage Height (feet)	Discharge
June 1, 1897	6.9	28,100
June 19, 1898	7.7	23,940
June 20, 1899	8.6	26,280
May 20, 1901	6.1	26,525
June 11, 1902	6.6[3/]	30,100
June 29, 1943	9.34	30,600
May 29, 1948	8.24	22,600
June 4, 1948	9.10	26,800
June 14, 1953	7.75	21,200
June 2, 1956	8.57	25,800
June 15, 1959	8.43	24,200
June 22, 1967	7.98	24,900
June 20, 1968	7.91	24,600
June 9, 1970	7.87	24,400
June 23, 1971	8.45	29,200
June 8, 1972	8.10	26,700
June 19, 1974	9.08	35,300[4/]

1/ From U.S.G.S. Gage Station located 4 miles south of Livingston.

2/ No U.S.G.S. gaging records are available for the years 1906-1928 and 1933-1937.

3/ Gage at different datum prior to 1905.

4/ Provisional.

FLOOD DESCRIPTIONS

June 1894 - Rapidly melting snows supplemented by rainfall caused the Yellowstone to flow from its banks. The flood crest reached Livingston on 4 June and floodwaters did not begin to recede until 8 June. Ninth Street Island, which was uninhabited at the time, was inundated. Livingston Island was flooded to a depth of three feet. Thirty-two homes in Riverside Addition were flooded on the first floor, and many city streets were damaged.

16 June 1918 - Rapidly melting snows caused flooding at Livingston on 16 and 17 June. Ninth Street Island and Livingston Island were covered to a depth of two feet, and the bridge between Livingston and Ninth Street Island collapsed. Twelve homes and three sheds in the Riverside Addition were flooded with one to three feet of water, and many streets were damaged.

27 May 1928 - Rapid melting of snows in the upstream basin caused flooding at Livingston on 27 May, and floodwaters began to recede on 29 May. Six homes on Ninth Street Island had first floor flooding and four homes had their grounds flooded. The upstream end of Livingston Island was flooded. Floodwaters filled Sacajawea Lagoon. One section of the bridge spanning the old channel at Sacajawea Park was destroyed by floodwaters.

20 June 1943 - The Yellowstone River began to rise at Livingston on 14 June, and the flood reached its peak on 20 June. Ninth Street Island was covered with two to three feet of water with damage to eight homes, a gravel plant, and roads. The golf course and a barn were flooded on Livingston Island. Water came within 2 inches of overtopping the levee. The maximum discharge was 30,600 cubic feet per second.

The following excerpts from the Livingston Enterprise describe the flood event of 1943:

June 10, 1943 - "The Yellowstone River, fed by a heavy runoff of snow water, began an upward surge again this morning - - climbing at the rate of an inch an hour . . ."

June 19, 1943 - "The river overflowed its bank about three and a half miles south of Livingston and water completely surrounded the Canyon View tourist cabins and the Earl Leonard Farm home. - - - Overflow had covered the main highway south of Livingston for a distance of 800 yards . . ."

22 June 1971 - Unseasonably warm weather caused melting of heavy snow cover upstream from Livingston. Heavy runoff caused the Yellowstone River to rise to a peak flow and stage of 29,200 c.f.s. and 8.45 feet, respectively. Ninth Street Island was flooded to a depth of about one foot.

Additional description of the 1971 flood as extracted from the Livingston Enterprise follows:

June 22, 1971 - "With 90 degree temperatures today and the same predicted for Wednesday, the Yellowstone is over its banks and flooding. High water is running over the road just above Eggar Ready Mix Plant . . ."

June 23, 1971 - "Water one foot over 9th Street Island Road. Started near Interstate bridge . . .

> "Ninth Street Island was cut in two Wednesday when the swift and muddy Yellowstone River overflowed its banks
>
> "About 175 yards of the island road is covered with about a foot of water starting near the Interstate bridge near Eggar Ready Mix Plant . . ."

21 June 1974 - Warm temperatures coupled with an exceptionally heavy mountain snowpack caused flooding in the Livingston vicinity that reached a peak stage of 9.08 feet on 21 June at the U.S.G.S. gage near Livingston. The National Weather Service called it the worst flooding in Livingston since 1943. The Ninth Street Island bridge and View Vista Road from the Main Street bridge to the golf course were closed. The school football and track fields were under water. Much of Ninth Street Island was flooded even though valiant attempts were made by local interests to keep out the floodwaters by dike construction and sandbagging. The Burlington-Northern Railroad bridge near Riverside Addition was damaged by the floodwaters. Photographs on pages 19 through 21 show flooding in the Livingston vicinity on 18 June 1974. River stages on this date at the U.S.G.S. gage located 4 miles south of Livingston varied from 8.7 feet to 8.9 feet.

Figure 11. Yellowstone River in the vicinity of Livingston, Montana. The Carter Bridge (reference point 5) is in the southeast corner of the photograph.

Figure 12. Yellowstone River in the vicinity of Livingston, Montana. Interstate 90 is at the extreme north

Figure 13. Yellowstone River in the vicinity of Livingston, Montana. The Interstate 90 bridge over the Yellowstone River is at the extreme south edge of this photograph. The south edge of this photograph overlaps the north edge of the photograph of Figure 12.

Figure 14. Yellowstone River in the vicinity of Livingston, Montana. The Burlington Northern Inc. bridge and the U.S. Highway 10 bridge over the Yellowstone River are shown in the center of the photo. The south edge of this photograph matches the north edge of the photograph of Figure 13.

FUTURE FLOODS

Floods of the same or larger magnitude as those that have occurred in the past could occur in the future. To determine the flood potential of the study area, two floods, the Intermediate Regional Flood (IRF) and Standard Project Flood (SPF) were analyzed and the results are presented in this report as a means of demonstrating the effects of large floods. To illustrate that large floods like these can happen, consider the Sun River at Great Falls, Montana on 9 June 1964. On that date the Sun River discharge amounted to an event which frequency was considered to be approximately half way between that of the IRF and SPF.

INTERMEDIATE REGIONAL FOOOD

The Intermediate Regional Flood is defined as one that occurs once in 100 years on the average, although it could occur in any year. The peak flow of this flood was developed from statistical analyses of streamflow records at the Livingston and Corwin Springs gaging stations. Within the study reach the Intermediate Regional Flood discharge on the Yellowstone River is 43,000 c.f.s.

STANDARD PROJECT FLOOD

The Standard Project Flood is defined as a major flood that can be expected to occur from a severe combination of meteorological and hydrological conditions that is considered reasonably characteristic of the geographical area in which the study area is located, exluding extremely rare combinations. The Corps of Engineers, in cooperation with the National Weather Service, has made comprehensive studies and investigations based on the past records of experienced storms and floods and has developed generalized procedures for estimating the flood potential of streams.

The Standard Project Flood is presented in this report as the practical upper limit of flooding. Storms that would produce this flood are uncommon, and it is difficult to assign frequencies of occurrence with any reasonable degree of accuracy. The Standard Project Flood discharge on the Yellowstone River in the study reach would be 60,000 c.f.s.

FREQUENCY

The Standard Project Flood is not the largest flood that can occur but the probability of larger floods becomes increasingly remote. As can be seen from gaging records, floods smaller than either the Intermediate Regional Flood or the Standard Project Flood are much more common, with an average peak annual discharge of about 20,900 c.f.s. for the gaging record at the U.S.G.S. gage on the Yellowstone River south of Livingston.

HAZARDS OF LARGE FLOODS

The extent of damage caused by any flood depends on the topography of the area flooded, depth and duration of flooding, velocity of flow, rate of rise, and developments on the flood plain. An Intermediate Regional or Standard Project Flood on the Yellowstone River in the study reach would result in the inundation of and subsequent damage to residential, commercial, recreational, and agricultural properties. Deep floodwater flowing at high velocity and carrying floating debris would create conditions hazardous to persons and vehicles attempting to cross flooded areas. In general, floodwater two or more feet deep and flowing at a velocity of 3 or more feet per second could easily sweep an adult person off his feet, thus creating definite danger of injury or drowning. Rapidly rising and swiftly flowing floodwater may trap persons in homes that are ultimately destroyed, or in vehicles that are ultimately submerged or floated. Water lines can be ruptured by deposits of debris and the force of floodwaters, thus creating the possibility of contaminated domestic water supplies. Damaged sanitary sewer lines could result in pollution of floodwater creating health hazards. Isolation of areas by floodwater such as Ninth Street Island could create Hazards in terms of medical, fire, or law enforcement emergencies.

Flooded area and flood damages - Water surface profiles for the Intermediate Regional and Standard Project Floods were developed for the study reach using the backwater computer program HEC-2, "Water Surface Profiles" developed by the U.S. Army Corps of Engineers. The computations were based on channel and flood plain conditions as represented by surveys conducted in the summer of 1973 and as supplemented by later field investigations.

The profiles, on plates 8 and 9 show the elevation of the water surfaces and water depths relative to the stream bed. The water surface elevations were used to determine flood limits on the cross sections and topographic maps and in turn the flood boundaries were transferred to the aerial photographs. The results are shown on the flooded areas maps, plates 3 through 7. An index to the flooded areas plates is on plate 2. Representative cross sections are illustrated on plates 10 and 11. The cross sections show ground elevations across the valley on both sides of the channel and depths of overbank flooding. Reference points, coinciding with the location of surveyed cross sections, are provided to locate flood elevations at intervals along the river. The reference point locations are shown on the flooded areas maps, profiles, and cross sections for correlation between drawings. Table 3 provides data at reference point locations, including distance along the main channel centerline, elevations of the stream bed, and elevations of the Intermediate Regional and Standard Project Floods.

Flood elevations for the two large potential floods can be obtained from the profiles, cross sections, or reference tables. For a specific situation where accuracy of flooded area is required, the flood limits can be more accurately established by determining water surface elevation from one of the above sources and then locating that elevation by survey on the flood plain.

This study indicates that upstream from reference point 4 and downstream from reference point 23 the flooded areas include mainly agricultural land with only intermittent farmsteads or ranches. However,

between these two points lies an area in which some portions are rather heavily developed such as the Riverside Addition. In this area the IRF inundates the area from 0 to 4 feet. On Livingston Island, the IRF flooding averages about 3 feet deep, thus flooding such areas as the high school facilities, the golf course, the Montana National Guard Armory, the drive-in theatre, and the fair ground facilities. Sacajawea Park and Ninth Street Island both receive flooding from the IRF. On Ninth Street Island, IRF flooding is 1 to 4 feet deep. Siebeck Island is also entirely inundated thus flooding a few residences and the gravel mining operation to depths ranging from 2 to 5 feet. Above Siebeck Island near reference point 10 IRF floodwater crosses U.S. Highway 89 and the Burlington Northern Railroad. Flooding in this area appears to be confined mainly to residential property. Keep in mind that the Standard Project Flood, due to its larger magnitude, can be expected to cause even more severe flooding and damages. Photographs on page 28 illustrate potential flood depths at various locations.

Obstructions to floodflows - Seven roadways, both highway and railroad, cross the entire Yellowstone River flood plain in the study reach. These roadways are the major obstructions to flood flows found in the study reach as can be seen from the water surface profile, plates 8 and 9. Interstate 90, the Burlington Northern Railroad, and U.S. Highway 89 (reference points 13, 29, and 30 respectively) have roadways crossing the flood plain which are high enough to prevent all floods studied in this report from flowing over the roadway thus forcing all floodwaters through the bridges. This situation coupled with the obstructions in the bridge due to piers creates higher stages upstream from these bridges. In addition, this phenomenon creates higher velocities in the immediate vicinity of the bridge increasing the chances for bridge failure due to erosion around bridge piers and abutments.

The remaining three roadways crossing the entire flood plain in the study reach are such that some water is able to overtop the

roadways reducing that flowing through the bridge. At the Carter Bridge (reference point 5) approximately 10% of the SPF flows over that portion of the roadway between the bridge and U.S. Highway 89. At the Burlington Northern Railroad and U.S. Highway 10 (reference points 22 and 23) approximately 13% of the IRF and 27% of the SPF is diverted from the river between reference points 19 and 22 due to the high roadway embankments at this point, especially that of the railroad crossing. This water flows northeast along the upstream side of U.S. Highway 10 and the Burlington Northern Railroad both of which slope downward across the flood plain as one progresses east. This diverted water eventually crosses these roadways spilling across the downstream flood plain as sheet flow shown on plates 5 and 6.

During large floods, such as the IRF and SPF, debris lying loose on the flood plain as well as buildings, trees, etc. normally attached to but dislodged from the flood plain by the water force, can lodge at downstream locations such as bridges creating flow obstructions. However, due to the fact that the occurrence and location of debris obstructions are indeterminant factors, no allowance in the hydraulic computations was made for this phenomenon. At bridges, only the physical characteristics of the bridge and roadway were considered.

Due to the infrequent occurrence of ice effects in the study reach as shown by the gaging records, no consideration was given to ice effects when performing the hydraulic computations. However, this does not mean that ice effects will never again play a role in water stages and ensuant flood damages during a flood event. In order to account for the possibility of future ice effects when considering flood plain development, all development susceptible to flood damages should be located at least 2 feet above the average elevation of the adjacent flood plain or at least 1 foot above the elevation of the IRF, whichever is greater. Bear in mind that in the event of complete channel blockage beneath a bridge, the water surface will increase until relief is accomplished by flow over the adjacent roadway. This may result in flooding higher than that considered in the flood plain development guidelines stated earlier in this paragraph.

Figure 15. Looking at the southwest corner of the Montana National Guard Armory.

Figure 16. Looking at the northeast corner of the city tennis court in Sacajawea Park.

Velocities of flow - Water velocities during flood depend largely on such parameters as size and shape of the cross sections, conditions of the stream, bed slope, etc., all of which vary on different streams and at different locations along the same stream. In the Livingston vicinity on the Yellowstone River, average velocities produced by the Intermediate Regional Flood range as high as 15 feet per second in the stream channel and as high as 4 feet per second on the flood plain. For the Standard Project Flood these values are 17 and 4.5 respectively. Localized velocities in constructed areas or flow constrictions may be even higher. Water flowing at these rates can inflict severe damage to bridge structures and flood plain development as well as pose a serious hazard to those persons in the path of the moving water.

Rate of rise and duration of flooding - Floods in the study reach normally result from snowmelt, or a combination of snowmelt and rainfall. However, flooding due to rainfall only is entirely possible. For large flows in the study reach the time from initial rise to peak discharge is about one day while the duration of the flood wave is about 3.5 days. Discharges in excess of the historical June average discharge of 13,400 c.f.s. can be expected to occur for 4 weeks during the snowmelt period running from late May to early July.

Bearing

The horizontal angular measurement of a line, in degrees, east or west of a north-south reference line.

Flood

An overflow on lands not normally covered by water and that are used or usable by man. Floods have two essential characteristics: the inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river or stream or an ocean, lake or other body of standing water.

Normally a flood is considered as any temporary rise in streamflow or stage, but not the ponding of surface water, that results in significant adverse effects in the vicinity. Adverse effects may include damages from overflow of land areas, temporary backwater effects in sewers and local drainage channels, creation of unsanitary conditions or other unfavorable situations by deposition of materials in stream channels during flood recessions, use of ground water coincident with increased streamflow, and other problems.

Flood Crest

The maximum stage or elevation reached by the waters of a flood at a given location.

Flood Plain

The relatively flat area or lowlands adjoining the channel of a river, stream or water course or ocean, lake or other body of standing water, which has been or may be covered by floodwater.

Flood Profile

A graph showing the relationship of water surface elevation to location, the latter generally expressed as distance above mouth for a stream of water flowing in an open channel. It is generally drawn to

show surface elevation for the crest of a specific flood, but may be prepared for conditions at a given time or stage.

Flood Stage

The stage or elevation at which overflow of the natural banks of a stream or body of water begins in the reach or area in which the elevation is measured.

Head Loss

The effect of obstructions, such as narrow bridge openings or buildings that limit the area through which water must flow, raising the surface of the water upstream from the obstruction.

Intermediate Regional Flood

A flood having a one percent probability of occurrence in any year or an average frequency of occurrence in the order of once in 100 years. The flood may occur in any year. It is based on statistical analysis of streamflow records and analyses of rainfall and runoff characteristics in the general region of the watershed.

Left Bank

The bank on the left side of a river, stream or water course, looking downstream.

Reference Point

A numbered point identifying a specific location for correlating the data shown in various forms throughout the report.

Right Bank

The bank on the right side of a river, stream or water course, looking downstream.

Sheet Flow

The water which is diverted from the main floodflow by obstructions and variances in topography. This water flows at shallow depths and normally at elevations different from the water flowing in the adjacent channel or on the adjacent flood plain. Due to the shallow depths and irregular flow patterns associated with this type of flow, computations to predict flow depth are considered impractical.

Standard Project Flood

The flood that may be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations. Peak discharges for these floods are generally about 40 percent to 60 percent of the Probable Maximum Floods for the same basins. Such floods, as used by the Corps of Engineers, are intended as practicable expressions of the degree of protection that should be sought in the design of flood control works, the failure of which might be disastrous.

Top of Waterway

This is the roof of the opening in a stream crossing through which water flows under normal conditions. It is the underside of the deck span - sometimes called "low steel", the roof of a box culvert or the crown of an arched or circular culvert.

TABLE 3

FLOOD PLAIN REFERENCE DATA

YELLOWSTONE RIVER, LIVINGSTON, MONTANA

Identification	Reference Point Number	Distance in Feet	Stream Bed Elevation Ft. M.S.L.	Intermediate Regional Flood Elevation Ft. M.S.L.	Standard Project Flood Elevation Ft. M.S.L.	Bearing
Upstream limits of study	1	78,420	4574.8	4589.4	4590.8	N 80° W
	2	74,975	4565.1	4577.5	4579.2	N 59° W
Cross Section 1-1	3	71,080	4542.0	4565.7	4567.6	N 77° W
	4	68,410	4548.3	4559.2	4560.4	N 70° W
Carter Bridge	5	65,980	4532.6	U/S 4555.2	U/S 4557.3	
				D/S 4553.3	D/S 4554.8	
	6	65,800	4538.0	4553.3	4554.8	N 90° E
	7	63,500	4530.1	4547.2	4548.2	N 67° E
	8	61,310	4527.1	4540.6	4542.9	N 75° E
Cross Section 2-2	9	57,950	4512.2	4532.7	4535.5	N 76° E
	10	54,750	4512.0	4525.4	4526.7	N 68° W
	11	51,780	4503.8	4515.8	4517.4	N 66° W
Cross Section 3-3	12	47,845	4490.7	4504.3	4506.4	N 82° W
Interstate 90	13	46,540	4481.8	U/S 4501.7	U/S 4503.8	
				D/S 4500.8	D/S 4502.7	
	14	46,340	4483.7	4499.9	4500.8	N 87° W
	15	44,130	4480.8	4493.9	4495.4	N 81° W

TABLE 3

FLOOD PLAIN REFERENCE DATA

YELLOWSTONE RIVER, LIVINGSTON, MONTANA

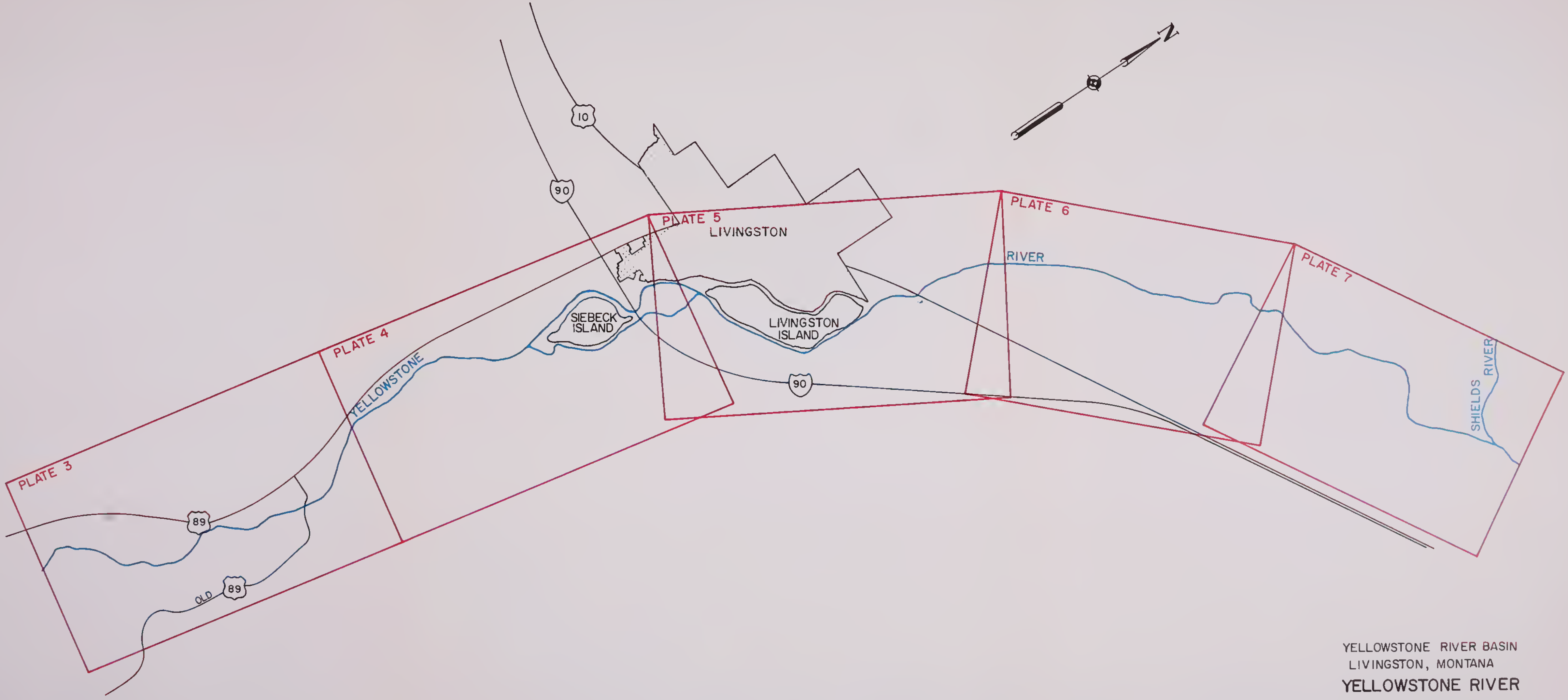
Identification	Reference Point Number	Distance in Feet	Stream Bed Elevation Ft. M.S.L.	Intermediate Regional Flood Elevation Ft. M.S.L.	Standard Project Flood Elevation Ft. M.S.L.	Bearing
	16	42,200	4476.2	4488.9	4490.2	N 39° W
	17	39,840	4468.1	4479.5	4480.7	N 30° W
Cross Section 4-4	18	36,920	4457.8	4473.2	4474.7	N 66° W
	19	35,210	4455.5	4469.1	4470.5	N 85° E
	20	33,530	4451.3	4465.4	4466.6	N 69° W
	21	31,870	4441.9	4459.4	4461.3	N 67° W
Highway 10 Bridge	22	31,680	4441.1	U/S 4459.4	U/S 4461.3	
				D/S 4459.1	D/S 4460.6	
Burlington Northern RR	23	31,425	4435.5	U/S 4459.1	U/S 4460.6	
				D/S 4456.0	D/S 4456.7	
	24	31,300	4436.0	4456.0	4456.7	N 65° E
	25	26,490	4429.8	4445.2	4445.9	N 45° W
Cross Section 5-5	26	21,470	4418.4	4432.5	4434.4	N 45° W
	27	15,880	4395.1	4417.5	4419.1	N 48° W
	28	9,360	4393.9	4405.9	4406.9	N 40° W
Burlington Northern RR	29	4,025	4369.3	U/S 4397.0	U/S 4400.7	
Highway 89 Bridge	30	3,940	4367.5			
				D/S 4394.6	D/S 4395.9	
	31	3,790	4378.0	4394.3	4395.9	N 26° W
Downstream limits of study	32	0	4373.9	4387.3	4388.8	N 22° W

YELLOWSTONE RIVER BASIN
LIVINGSTON, MONTANA

YELLOWSTONE RIVER

PLATE INDEX MAP

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
NOVEMBER 1974



YELLOWSTONE RIVER BASIN
LIVINGSTON, MONTANA

YELLOWSTONE RIVER

PLATE INDEX MAP

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
NOVEMBER 1974

YELLOWSTONE RIVER BASIN
LIVINGSTON, MONTANA

YELLOWSTONE RIVER FLOODED AREAS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
NOVEMBER 1974

INTERMEDIATE REGIONAL FLOOD
STANDARD PROJECT FLOOD

CHANNEL CROSS SECTION

REFERENCE POINT-ALSO LOCATIONS OF SURVEYED CROSS SECTIONS

NOTES.
1. FOR ILLUSTRATED CROSS SECTION, SEE PLATE 10.
2. FOR PROFILE, SEE PLATES 8 & 9.
3. FOR FLOOD ELEVATIONS AT THE REFERENCE POINT, SEE TABLE 3.

SCALE IN FEET
1000 0 1000 2000

YELLOWSTONE RIVER BASIN
LIVINGSTON, MONTANA

YELLOWSTONE RIVER
FLOODED AREAS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
NOVEMBER 1974

INTERMEDIATE REGIONAL FLOOD
STANDARD PROJECT FLOOD

CHANNEL CROSS SECTION

REFERENCE POINT - ALSO LOCATIONS OF SURVEYED CROSS SECTIONS

NOTES:

1. FOR ILLUSTRATED CROSS SECTION, SEE PLATE 11.
2. FOR PROFILE, SEE PLATE 9.
3. FOR FLOOD ELEVATIONS AT THE REFERENCE POINT, SEE TABLE 3

SCALE IN FEET

1000 0 1000 2000

YELLOWSTONE RIVER BASIN
LIVINGSTON, MONTANA

YELLOWSTONE RIVER
FLOODED AREAS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
NOVEMBER 1974

INTERMEDIATE REGIONAL FLOOD

STANDARD PROJECT FLOOD

CHANNEL CROSS SECTION

REFERENCE POINT-ALSO LOCATIONS OF SURVEYED CROSS SECTIONS

NOTES:

1. FOR ILLUSTRATED CROSS SECTION, SEE PLATE 11.
2. FOR PROFILE, SEE PLATE 9
3. FOR FLOOD ELEVATIONS AT THE REFERENCE POINT, SEE TABLE 3

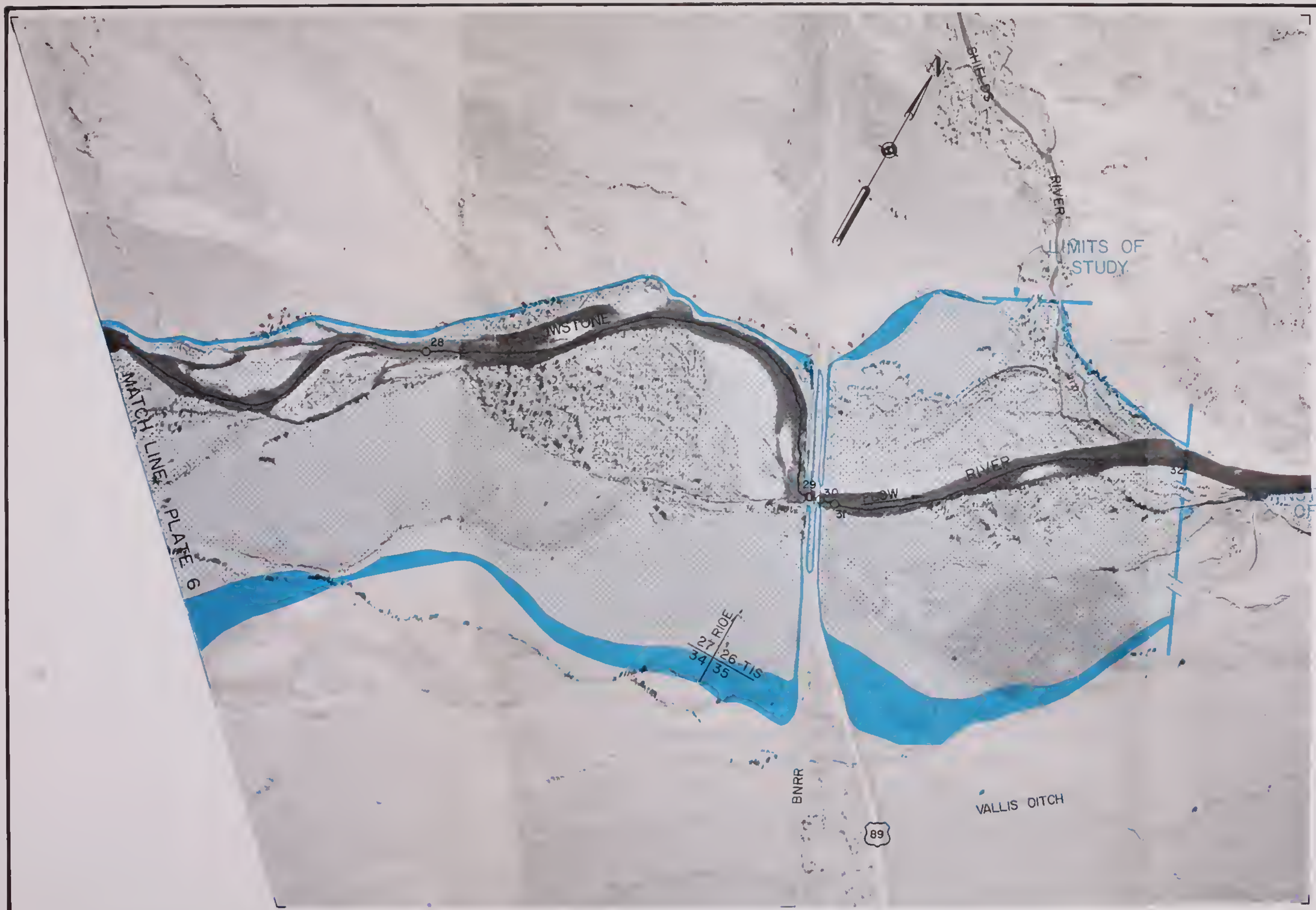
SCALE IN FEET

1000 0 1000 2000

YELLOWSTONE RIVER BASIN
LIVINGSTON, MONTANA

YELLOWSTONE RIVER FLOODED AREAS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
NOVEMBER 1974



INTERMEDIATE REGIONAL FLOOD

STANDARD PROJECT FLOOD

CHANNEL CROSS SECTION

REFERENCE POINT-ALSO LOCATIONS OF SURVEYED CROSS SECTIONS

NOTES.

1. FOR PROFILE, SEE PLATE 9.
2. FOR FLOOD ELEVATIONS AT THE REFERENCE POINT, SEE TABLE 3

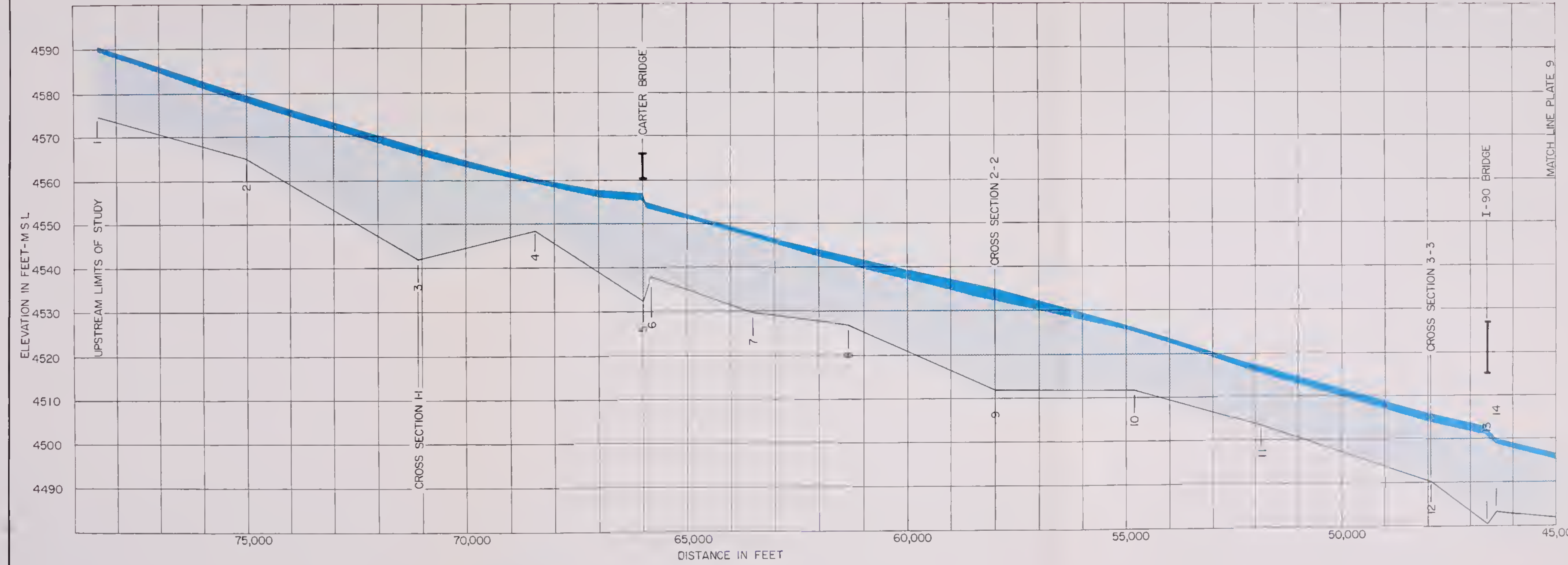
SCALE IN FEET

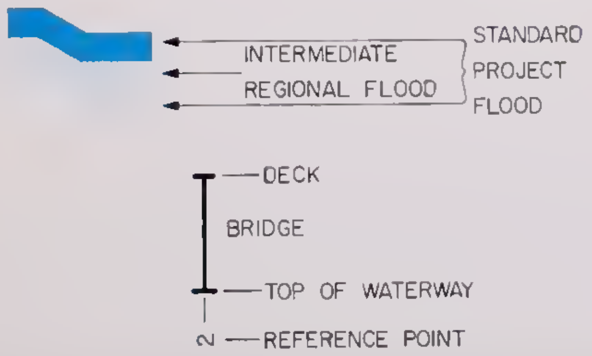
1000 0 1000 2000

YELLOWSTONE RIVER BASIN
LIVINGSTON, MONTANA

YELLOWSTONE RIVER
FLOODED AREAS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
NOVEMBER 1974





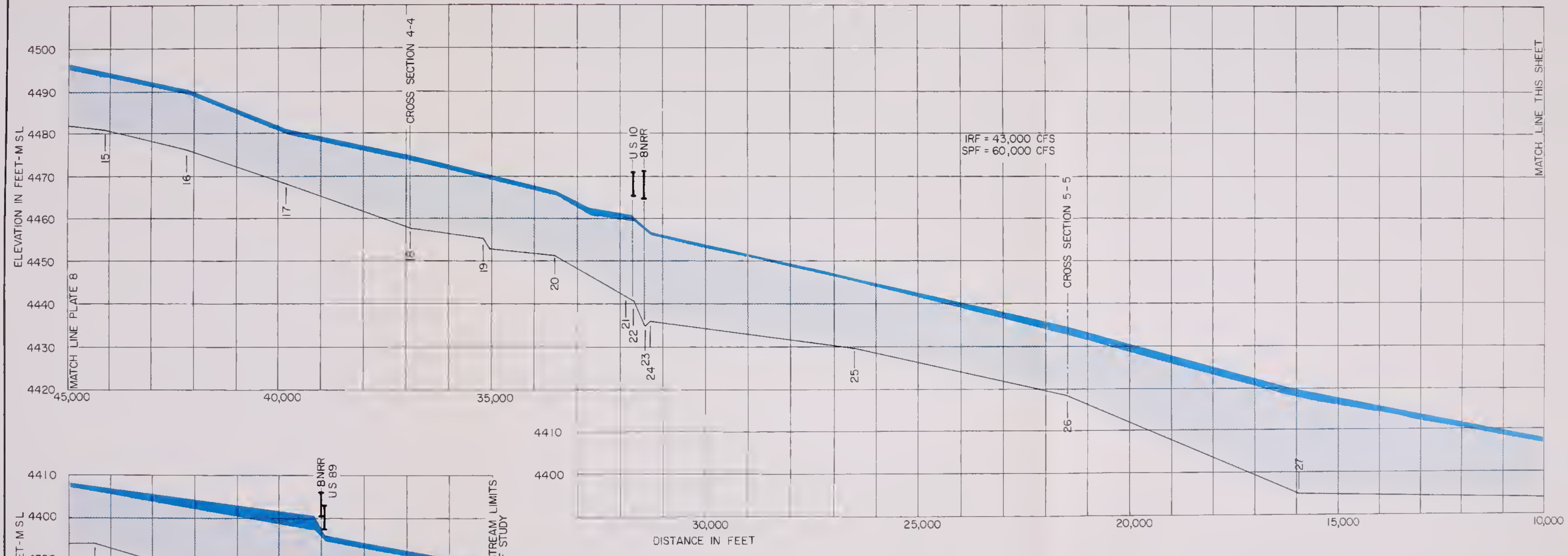
NOTES

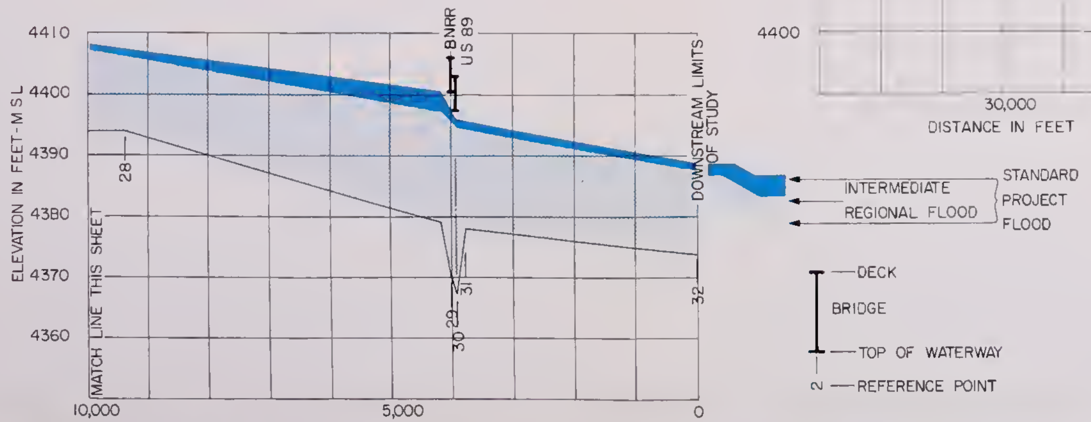
1. FOR LOCATION OF CROSS SECTIONS, SEE PLATES 3 & 4
2. FOR ILLUSTRATED CROSS SECTIONS, SEE PLATE 10
3. FOR FLOOD ELEVATIONS AT THE REFERENCE POINTS, SEE TABLE 3.

YELLOWSTONE RIVER BASIN
LIVINGSTON, MONTANA

YELLOWSTONE RIVER PROFILE

U S ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
NOVEMBER 1974





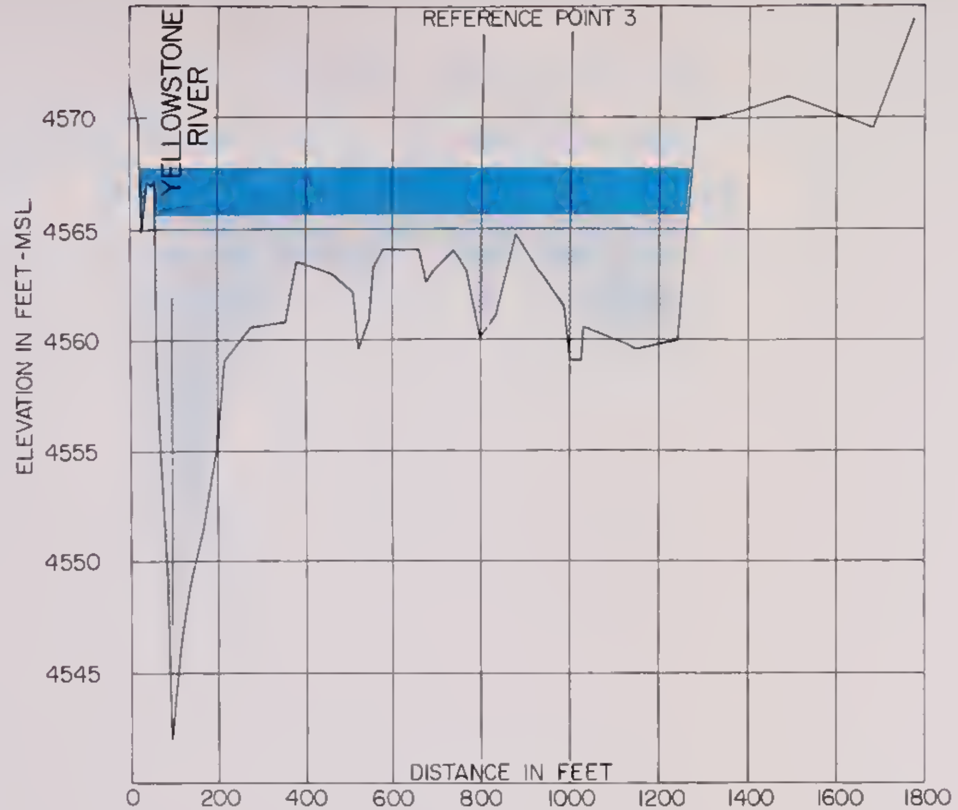
NOTES

1. FOR LOCATION OF CROSS SECTIONS, SEE PLATES 5,6 & 7
2. FOR ILLUSTRATED CROSS SECTIONS, SEE PLATE 11
3. FOR FLOOD ELEVATIONS AT THE REFERENCE POINTS, SEE TABLE 3.

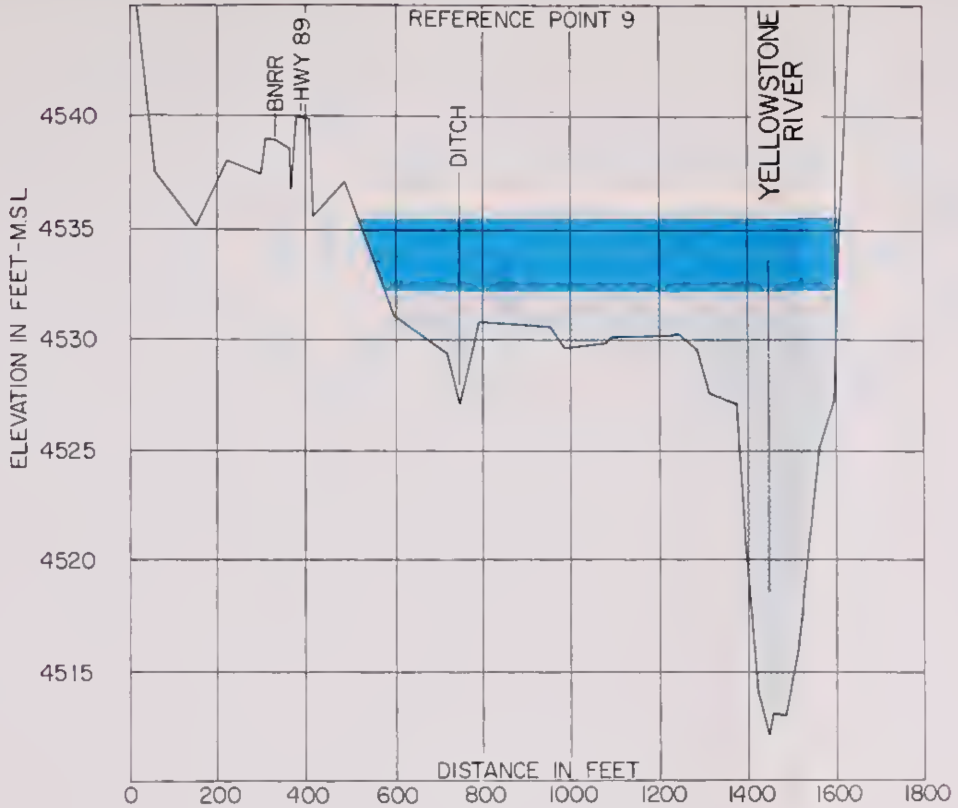
YELLOWSTONE RIVER BASIN
LIVINGSTON, MONTANA

YELLOWSTONE RIVER
PROFILE

U S ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA,NEBRASKA
NOVEMBER 1974



CROSS SECTION 1-1



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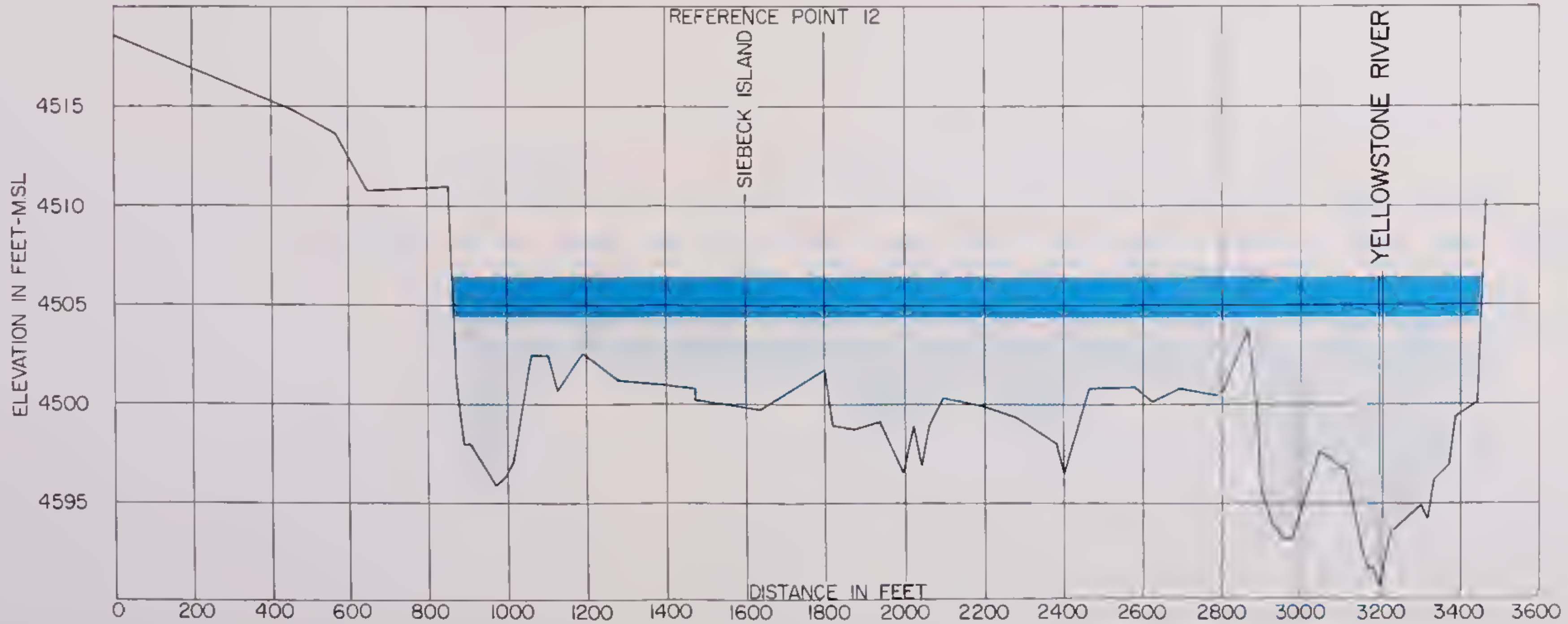


CROSS SECTION 3-3

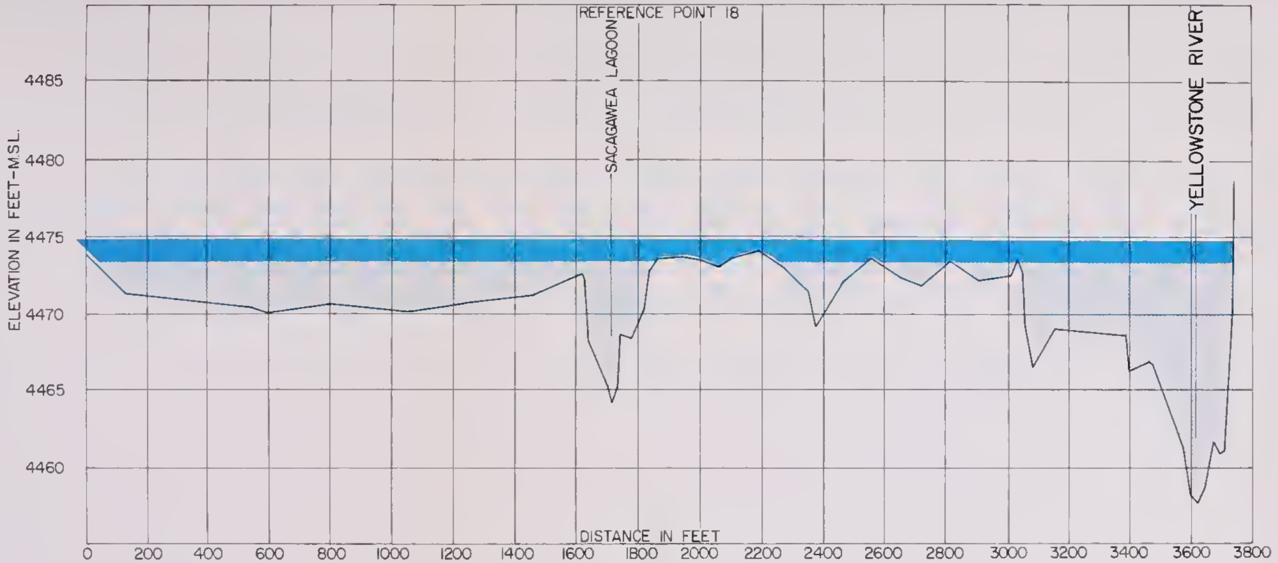
NOTES
1. FOR LOCATION OF CROSS SECTIONS, SEE PLATES 3 & 4

YELLOWSTONE RIVER BASIN
LIVINGSTON, MONTANA

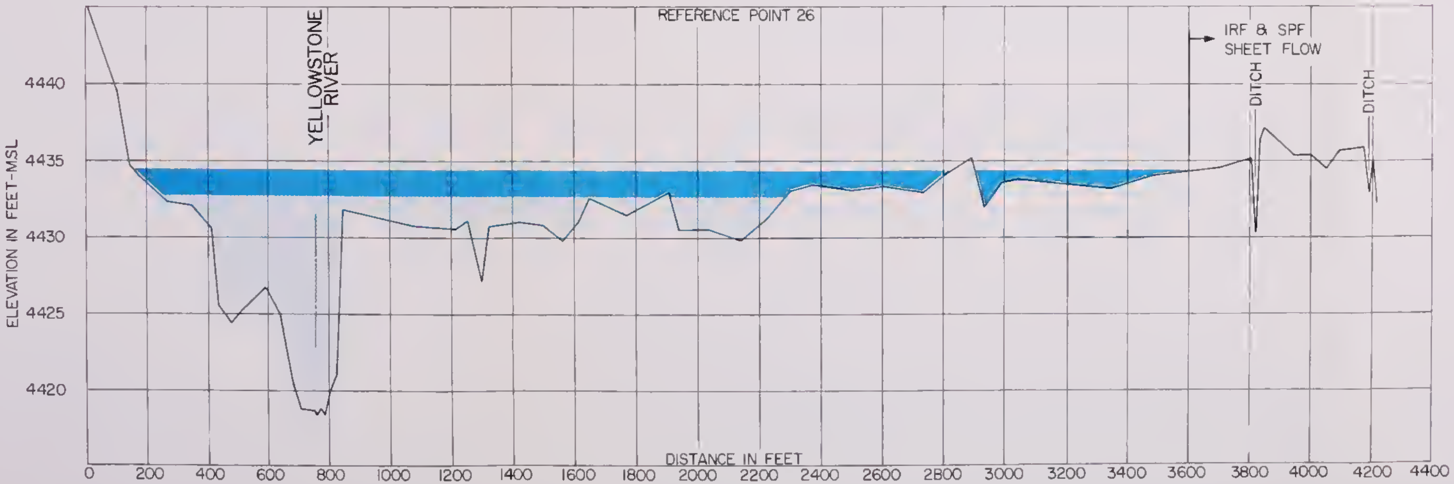
YELLOWSTONE RIVER
CROSS SECTIONS

U S ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

NOVEMBER 1974



CROSS SECTION 4-4



CROSS SECTION 5-5

INTERMEDIATE REGIONAL FLOOD

STANDARD PROJECT FLOOD

NOTES

1 FOR LOCATION OF CROSS SECTIONS, SEE PLATES 5 & 6

YELLOWSTONE RIVER BASIN
LIVINGSTON, MONTANA

YELLOWSTONE RIVER
CROSS SECTIONS

U S ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

NOVEMBER 1974